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LAKE ERIE ENFORCEMENT CONFERENCE TECHNICAL COMMITTEE REPORT

George L. Harlow

Federal Water Pollution Control Administration
Washington, D. C.

1 June 1967

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REPORT OF THE

LAKE ERIE ENFORCEMENT CONFERENCE TECHNICAL COMMITTEE

June, 1967

LETTER OF TRANSMITTAL

March 22, 1967

Dear Sir:

The Lake Erie Enforcement Conference Technical Committee is pleased to present this final report to the Lake Erie Enforcement Conferees.

The Committee was directed to explain the problems related to nutrients and over-enrichment of Lake Erie.

By holding eight meetings covering 16 days, in which the Committee received information and advice from 26 leading authorities in water-oriented disciplines, a thorough review and analysis of the problems was permitted. This report represents the findings of the Committee.

George L. Harlow
Chairman

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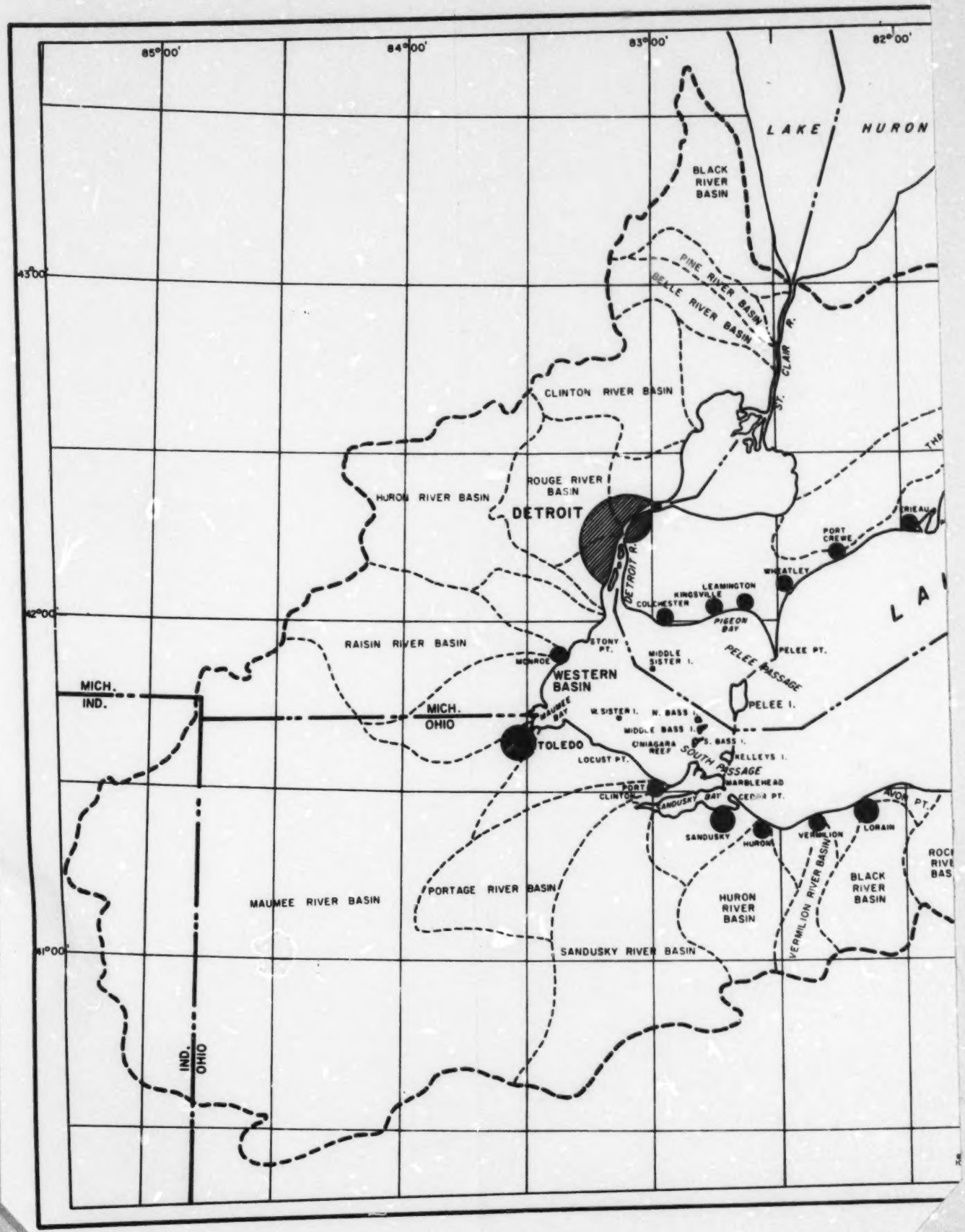
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DETROIT
DETROIT R.
PORT CREWE
WHEATLEY
LEAMINGTON
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PIGEON BAY
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MONROE
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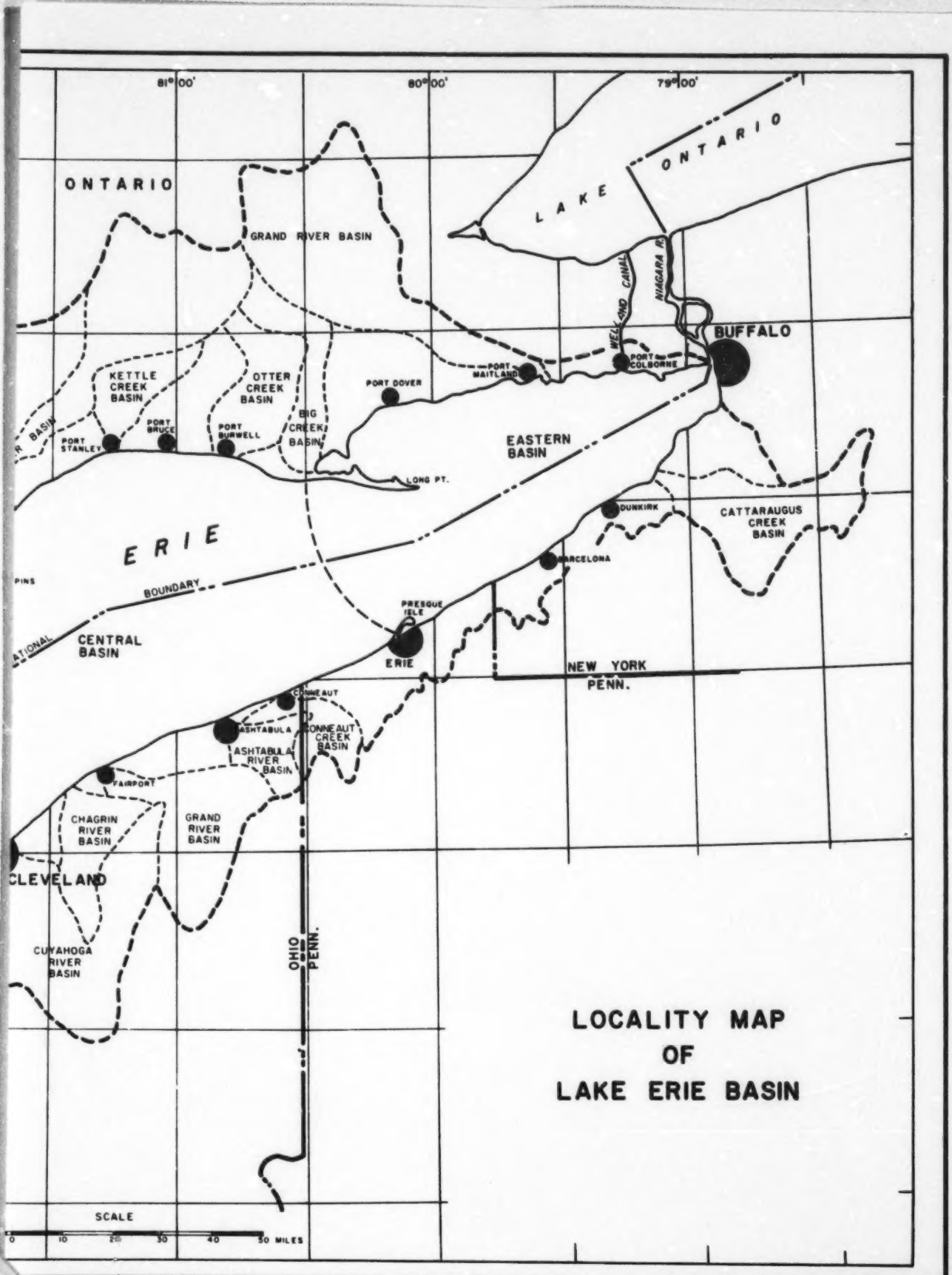


LOCALITY MAP
OF
LAKE ERIE BASIN

FIGURE 1

INTRODUCTION

At the request of the Honorable James A. Rhodes, Governor of the State of Ohio, Secretary Anthony Celebreeze of the United States Department of Health, Education, and Welfare, under authority granted in Section 8 of the Federal Water Pollution Control Act of 1961, called a conference on pollution of Lake Erie and its tributaries. The conference was held in two sessions, in Cleveland on August 3-5, 1965 and in Buffalo on August 10-12, 1965. The conferees were as follows:

Dr. B. A. Poole, Indiana
Mr. Loring Oeming, Michigan
Dr. E. W. Arnold, Ohio
Mr. George Eagle, Ohio
Mr. Fred Mohr, Ohio
Mr. Richard Boardman, Pennsylvania
Mr. Robert Hennigan, New York
Mr. H. W. Poston, Federal Government

The conference chairman was Mr. Murray Stein, Federal Water Pollution Control Administration (FWPCA), Washington, D. C.

After hearing a Federal report on pollution in the conference area, reports on pollution control activities in each of the five States, and statements by others, the conferees agreed unanimously on a summary containing conclusions and recommendations that was later issued by the Secretary of the Department of Health, Education, and Welfare on November 12, 1965.

One of the summary recommendations stated:

> "The conferees will establish a Technical Committee as soon as possible which will evaluate water quality problems in Lake Erie relating to nutrients and make recommendations to the conferees within six months after the issuance of this Summary."

At a conferees' meeting in Cleveland on September 1, 1965, members of the technical committee were selected. On December 17, 1965, the conferees met with the designated committee members and the Lake Erie Enforcement Conference Technical Committee was formally established. The following members and their alternates were appointed:

State	Member	Alternates
Michigan	Carlos Fetterolf, Jr.	---
Indiana	Perry Miller	John Winters
Ohio	J. E. Richards	George Garrett
Pennsylvania	Walter Lyon	Daniel Bardarik Paul Heitzenrater
New York	Robert Hennigan	Donald Stevens

Mr. Grover Cook, FWPCA, was appointed Chairman of the committee, and served until January, 1967. From January, 1967 until the present Mr. George Harlow, FWPCA, has been Chairman of the committee. Mr. Frank Hall, FWPCA, is Secretary to the committee.

At the September 1, 1965 meeting, the conferees asked the committee to investigate the following aspects of Lake Erie problems:

"(1) Determine the situation, past and present, in Lake Erie with regard to nutrient levels and the related consequences. Also determine how the existing situation would be modified by various pollution control methods.

(2) Determine the nutrient levels or concentrations which constitute interstate pollution of Lake Erie.

(3) Determine the nutrient levels or concentrations which should be established as water quality objectives in various parts of Lake Erie.

(4) Determine the sources of nutrients entering Lake Erie and the percentages originating from: detergents; other municipal wastes; industrial wastes; and agricultural land use.

(5) Determine the nutrient balance of Lake Erie.

(6) Identify the various nutrients affecting Lake Erie water quality and determine which are susceptible to control."

On June 22, 1966, a third meeting of the Lake Erie Enforcement Conferees was held in Cleveland, Ohio at which Chairman Stein added a seventh instruction to those listed above:

(7) Identify other lake problems and explore ways of dealing with them.

At that third meeting, the conferees, presided over by Secretary of the Interior Stewart Udall, were presented with a report by the Technical Committee which had been formed. The conferees did not consider the report to be a consensus of all Technical Committee members. The Technical Committee was directed to continue its deliberations and revise the Interim Report to reflect a consensus. It was decided by Secretary Udall and the conferees that it should be called an Interim Report.

The Technical Committee reviewed and revised the June 22, 1966 Interim Report to reflect a consensus of all committee members and submitted it to the conferees. The report was retitled "Interim Report of the Lake Erie Enforcement Conference Technical Committee, June, 1966 (Revised, November, 1966)."

This March, 1967 report expands upon the revised Interim Report to include discussion, conclusions and recommendations regarding each of the seven instructions. It reflects the consensus of all the committee members.

The Lake Erie Enforcement Conference Technical Committee wishes to acknowledge the advice and invaluable information provided to the committee by many individuals. The following persons have graciously given of their time to attend and contribute to meetings of the committee or to otherwise provide information:

Dr. Alfred M. Beeton, University of Wisconsin, Milwaukee, Wisc.
Mr. Kenneth Biglane, FWPCA, Washington, D. C.
Mr. Russell Brant, Ohio Department of Natural Resources, Columbus, Ohio
Mr. Ted Brenner, Soap and Detergent Association, New York, N. Y.
Dr. N. Wilson Britt, Ohio State University, Columbus, Ohio
Mr. Charles Bueltman, Soap and Detergent Association, New York, N. Y.
Dr. Richard Engelbrecht, University of Illinois, Urbana, Illinois
Mr. Frederick Fuller, FWPCA, Chicago, Illinois
Mr. Harold Hall, FWPCA, Chicago, Illinois
Mr. Robert Hartley, FWPCA, Cleveland, Ohio
Mr. C. E. Herdendorf, Ohio Department of Natural Resources, Sandusky, Ohio
Dr. Matthew Hohn, Central Michigan University, Mt. Pleasant, Michigan
Mr. G. LaMar Hubbs, FWPCA, Cleveland, Ohio
Mr. Conrad Kleveno, FWPCA, Cleveland, Ohio
Dr. Edward Martin, FWPCA, Washington, D. C.
Mr. Stephen Megregian, FWPCA, Chicago, Illinois
Mr. John Neil, Ontario Water Resources Commission, Toronto, Canada
Mr. C. Ray Ownbey, FWPCA, Chicago, Illinois
Dr. Charles Priesing, FWPCA, Ada, Oklahoma
Dr. Gerard Rohlich, University of Wisconsin, Madison, Wisconsin
Dr. Stanford Smith, U. S. Bureau of Commercial Fisheries, Ann Arbor, Michigan
Dr. Jacob Verduin, Eastern Illinois University, Charleston, Illinois
Mr. David Wagner, FWPCA, Chicago, Illinois
Mr. John Wirts, Cleveland Easterly Pollution Control Center, Cleveland, Ohio

The committee is especially grateful to Mr. John Carr of the Bureau of Commercial Fisheries, U. S. Department of the Interior, and Mr. Al Harris of the Ontario Water Resources Commission, who participated in the work of the committee and assisted in the preparation of this report.

DISCUSSION OF FINDINGS

Instruction 1(A) "Determine the situation, past and present, in Lake Erie with regard to nutrient levels and the related consequences."

Recent environmental changes in Lake Erie were reported by specialists in many water-oriented disciplines.

Chemical Conditions. Records from many sources over the past 50 years show an increase in chlorides from 8 milligrams per liter (mg/l) to 26 mg/l, and an increase in sulfates from 13 mg/l to 23 mg/l. Good long-term records for phosphorus are not available, but recent information indicates that there has been a substantial increase in phosphorus inputs and an increase in concentration in the lake. Most early limnologists considered that nitrogen was the limiting nutrient for algal growth. Therefore, tests for phosphorus were not common, and when phosphorus analyses were made, a variety of techniques and reporting procedures were used. (Appendixes B and C contain a suggested procedure for reporting and testing.)

During summer thermal stratification, dissolved oxygen (DO) is substantially reduced in the bottom waters of a large area in the central basin. This was first reported in 1929 and has been observed many times since. However, the DO now reaches zero and the area where low DO occurs is widening. This DO deficit results largely from the decomposition of algae and may be explained as follows:

a. Algae are produced in excessive amounts in the western basin and along the shoreline of the central and eastern basins as a manifestation of plant nutrient concentrations.

b. The algae cells drift around the lake and eventually settle to the bottom. During this settling process, oxygen is consumed by decay of dead cells.

c. Decaying cells accumulate in the bottom muds and exert oxygen demand as decomposition continues.

d. During summer periods of thermal stratification, when the bottom layer of water is isolated from the oxygen-rich upper layer, the available oxygen in the lower layer may be used up by the decay process.

e. The rate of consumption is greatly intensified when the organically enriched sediments are stirred into suspension.

The theoretical relationship between phosphorus inputs, organic carbon produced by biological processes, and DO depletion was presented to the committee.

Physical Conditions. Records of lake levels have been kept for over a hundred years and fluctuations of several feet are well known. When the lake is high, shore erosion occurs. This has contributed to nutrient increases in the lake. When lake levels are low, as in the early sixties, a larger shoal area is affected by sunlight and a larger crop of Cladophora (attached algae) has been observed.

Harbor and channel modifications have changed current pattern in localized areas and have increased silt inputs. The dumping of dredged material from these operations has changed the composition of the lake bottom and has increased inputs of nutrients.

Lake currents are mostly the product of winds. At four feet above the lake bottom, current velocities as high as 2.0 feet per second have been recorded. A strong wind will induce thorough mixing more than 30 feet deep. Strong winds also produce an oscillation of the thermocline that results in mixing of the bottom waters, but without intermixing of the upper and lower water layers. This lack of intermixing is significant in that the oxygen-rich water of the upper layer (epilimnion) does not replenish the depleted oxygen supply in the lower layer (hypolimnion), and oxygen demanding material and nutrients do not leave the bottom waters during periods of thermal stratification.

Another physical characteristic that bears upon the overall problem is water temperature. Records show, using 10-year moving means, that there has been a rise of 2° F since 1918. The warming trend of the lake follows that of the climate.

Algae. Both the microscopic suspended algae called phytoplankton, or planktonic algae, and the filamentous algae that grow attached to firm substrata are responsible for nuisance conditions in Lake Erie. Of the two types, filamentous Cladophora has been troublesome for a longer time. The beaches on Kelleys Island have been littered with Cladophora for at least 30 years.

Chemical methods of Cladophora control have not been too successful. To be effective, the chemicals should be applied during periods of calm in the early part of the growing season. By present standards, chemical control is expensive, especially when used for large areas. It is estimated that for effective control, at least 350 square miles of Lake Erie would have to be treated.

Lake-wide information on phytoplankton is rather sparse. However, there are good data on samples taken in Cleveland since 1929 and in the South Bass Island area over the past few years. According to Davis (1966) these records indicate three main changes: 1. A gradual increase in the total quantity of phytoplankton has occurred. The average increase between 1927 and 1964 amounted to 44.3 cells/ml/yr and from 1956 to 1964 the increase was 122.0 cells/ml/yr; 2. There has been a change from typical, relatively brief vernal and autumnal phytoplankton pulses every year to pulses that are not only much more massive, but also more extensive. This has resulted in complete obliteration of the winter minimum and a considerable reduction of the

length of the summer minimum; 3. There have been important changes of dominant algal genera. In 1929, the diatoms Fragilaria, Asterionella, and others that are common in Lakes Superior, Huron, and Michigan were predominant. Today, diatoms such as Stephanodiscus and Cyclotella, typical of enriched lakes, are the more abundant kinds. Dense blooms of highly undesirable blue-green algae have been observed in the area of the lake west of Cleveland. These blooms typically occur in eutrophic lakes and are rare in lakes like Superior and Huron.

Bottom Dwelling Animals. Prior to 1953, burrowing mayflies were the dominant bottom-dwelling animals in the western basin. In September 1953, this basin became thermally stratified, dissolved oxygen was depleted in the lower layer of water, and a catastrophic die-off of mayflies took place. The overall occurrence of these important fish food organisms has steadily declined. They have been almost completely replaced by sludgeworms and midge larvae. Major factors in the decline of the mayflies have been low DO and change in composition and distribution of the bottom sediments.

Fishes. Dramatic changes have occurred in the Lake Erie fishery since 1920. Although Lake Erie remains the most productive of all the Great Lakes, the catch is of poorer quality than it used to be. Yellow perch are still abundant. Blue pike have disappeared and walleyes, whitefish, and herring are scarce. Low DO that occurs in the hypolimnion of the central basin creates an unfavorable habitat for both fish and the organisms upon which they feed.

Conditions must be made suitable for the more desirable fish and aquatic organisms during all stages of their life cycle. Certain adult fish spawn on reefs and gravel areas. However, heavy wave action often washes the eggs into the degraded bottom muds prior to hatching. The oxygen deficient sediments and overlying waters in many parts of the lake are entirely unsuitable for the successful completion of their life cycles. The percentage of eggs that hatch is greatly reduced and those young fish which at times develop from the eggs die rapidly and the propagation of the more desirable species ceases. These are subsequently replaced in time by species which are more tolerant to degraded environmental conditions. Total fish productivity is not necessarily impaired, but the percentage of desirable species is greatly reduced in favor of the less desirable species. The ultimate result would be a highly productive lake full of coarse fish.

Instruction 1(B) "Also determine how the existing situation would be modified by various pollution control methods."

The existing situation will be modified by the elimination or reduction of organic material, nutrients, and silts from municipal, industrial, and agricultural sources. Secondary or equivalent treatment must be provided for all wastes. Treatment processes and techniques must be developed for the substantial removal of phosphorus from sewage and industrial wastes. It is reported that at several locations in the southwestern United States, modifications of activated sludge type of treatment have increased the removal of phosphorus. Additional demonstration projects are needed to prove the applicability of these modifications to activated sludge plants in the Lake Erie Basin. Development of new processes should be encouraged for use in augmenting and improving those modifications already under study for activated sludge-type plants. Additional modifications must be developed and employed to effect high phosphorus removals in other type plants.

Instruction II. "Determine the nutrient levels or concentrations which constitute interstate pollution of Lake Erie."

Instruction III. "Determine the nutrient levels or concentrations which should be established as water quality objectives in various parts of Lake Erie."

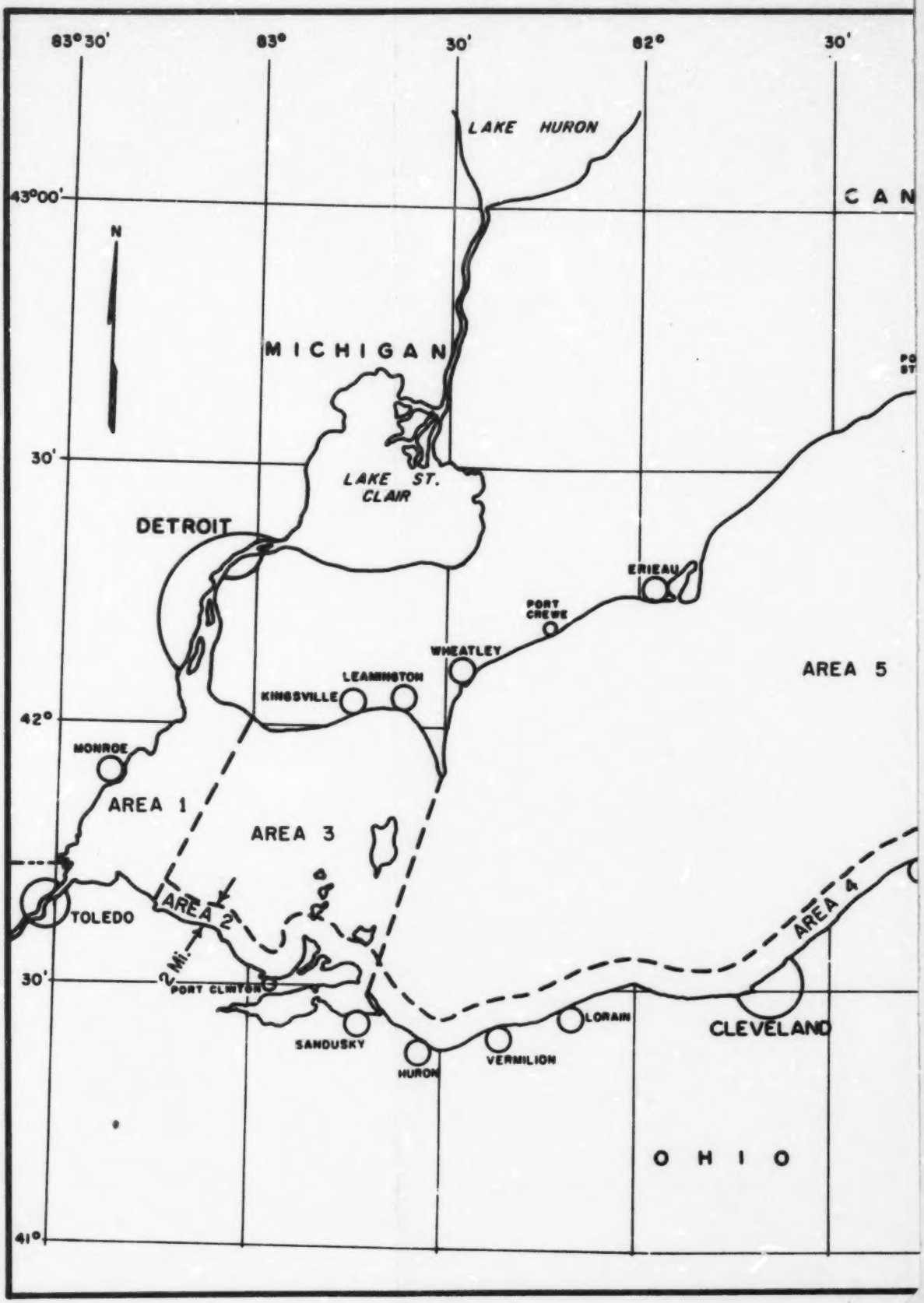
It was the opinion of the committee members that Instructions II and III should be considered jointly and the following statements are made accordingly.

A determination was made of existing concentrations of total phosphorus and soluble phosphorus in Lake Erie. The following tables present data for seven areas of the lake and for the major harbors (see Figure 2 and Tables 1 and 2).

It was the finding of the conferees, and the members of the committee agree, that Lake Erie is over-enriched. The highest nutrient concentrations and excessive crops of algae are found in the western basin and in the shoreline area. It is the committee's opinion that pollution from nutrients is occurring at these present concentrations. Total phosphorus ranged from 0.015 mg/l in mid-lake waters of the central and eastern basins to 0.090 mg/l in the western basin and along the Ohio shoreline. Soluble phosphorus ranged from 0.008 mg/l to 0.050 mg/l in the same areas of the lake. Inorganic nitrogen varied from average values of 0.25 mg/l to 0.75 mg/l. For comparison, in southern Lake Huron where eutrophication is not a problem, 50 analyses for total PO_4-P were reported less than 0.008 mg/l and 14 additional samples averaged 0.03 mg/l; 54 analyses for soluble PO_4-P were reported less than 0.008 mg/l and 10 additional samples averaged 0.03 mg/l. Inorganic nitrogen in southern Lake Huron averaged 0.25 mg/l. The concentrations of nitrogen and phosphorus in the central and eastern basins of Lake Erie are not much greater than the concentrations in Lake Huron.

The only information available on levels of phosphorus and nitrogen that has provided a guide for the development of suitable criteria necessary to restore Lake Erie water quality was that of Sawyer (1954) in his classical Madison, Wisconsin lake studies. He found that when the concentration "of inorganic nitrogen and [soluble] phosphorus exceed 0.30 ppm and 0.01 ppm respectively, at the start of the active growing season (time of spring turnover in northern climates), a season with nuisance blooms [of algae] would follow."

Other experts that met with the committee could not provide information to support or dispute these figures and therefore did not disagree with Sawyer's values. Sawyer's values compare very closely with water quality in southern Lake Huron and mid Lake Erie where prolific growths do not occur. Based on this information and the available chemical and biological data, the committee determined that the following concentrations of nutrients should be established as water quality objectives in various parts of Lake Erie: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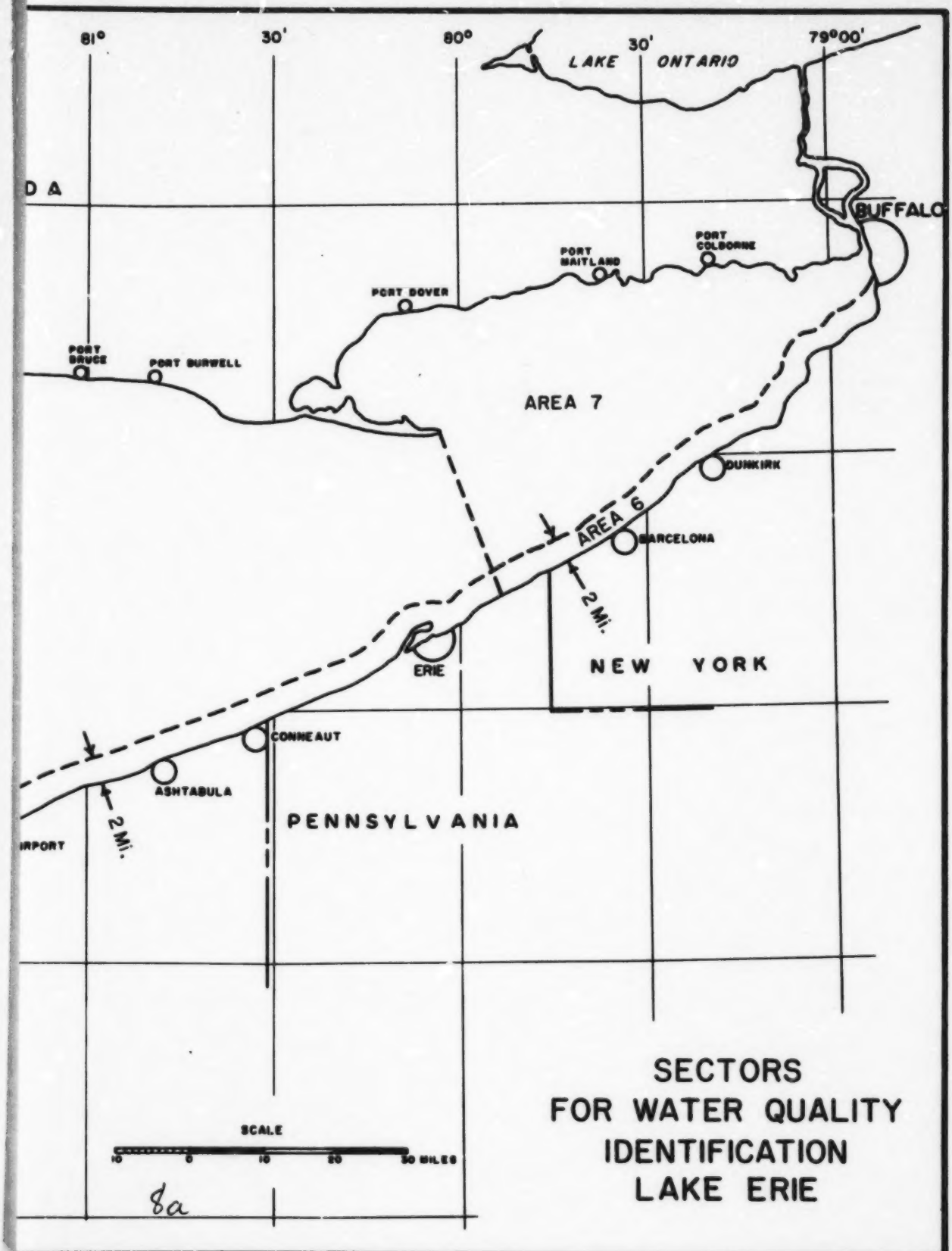

SECTORS
FOR WATER QUALITY
IDENTIFICATION
LAKE ERIE

FIGURE 2

Location (See Fig. 2)	Total PO_4-P mg/l	Sol PO_4-P mg/l	Inorganic N mg/l
Areas 1, 2, 3, & 4	0.025	0.010	0.3
Areas 5, 6 & 7	0.015	0.007	0.3

TABLE 1

PHOSPHORUS CONCENTRATIONS IN LAKE ERIE

Area	Total PO_4-P, mg/l #Samples	Max.	Min.	Avg.	Sol. PO_4-P, mg/l #Samples	Max.	Min.	Avg.
1	128	0.67	0.013	0.09	320	0.57	0	0.05
2				*	13	0.08	0	0.03
3				*	57	0.07	0	0.02
4				*	874	0.65	0	0.04
5				*	418	0.20	0	0.01
6				*	30	0.61	0	0.01
7				*	174	0.03	0	0.01

TABLE 2

PHOSPHORUS CONCENTRATIONS IN HARBOR AREAS

Area	#Samples	Tot. PO_4-P. mg/l Max.	Min.	Avg.	Sol. PO_4-P. mg/l Max.	Min.	Avg.
Detroit R., Mouth	38	0.67	0.013	0.13	0.37	0.013	0.08
Maumee Bay	13	0.30	0.013	0.11	0.3	0.07	0.05
Sandusky, O.	56			*	0.80	0	0.08
Lorain, O.	54			*	0.15	0	0.02
Cleveland, O.	98			*	0.68	0	0.06
Fairport, O.	99			*	0.31	0	0.02
Ashtabula, O.	66			*	0.66	0	0.05
Erie, Pa.	119			*	0.46	0	0.09

* No data, but using the ratio of total to soluble phosphates found for the Detroit River mouth and Maumee Bay, it is assumed for other areas of the lake that the total phosphates would be approximately double the soluble values.

Instruction IV. "Determine the sources of nutrients entering Lake Erie, and the percentages originating from: detergents, other municipal wastes, industrial wastes, and agricultural land use."

Phosphates in detergents. The average discharge of total phosphorus (P) in domestic wastes on a per capita per year basis is 3.5 pounds (Sawyer, 1965). One pound is from human excreta and 2.5 pounds are from detergents. In the Lake Erie basin, the phosphorus contribution from municipal wastes is 80 percent, which can be broken down by sources as human excreta, 22 percent; detergents, 53 percent; and other sources, 5 percent.

Representatives of the soap and detergent industry informed the Technical Committee that an acceptable substitute for phosphate was not presently available. The importance of polyphosphates lies in synergistic effects obtained when used with surfactants. Significant loss of cleaning power results when substitutes are used.

Some of the important functions of phosphates in detergents are to provide alkalinity, increase dirt and grease removing capacity, reduce redeposition of dirt, soften the water, limit scum formation, and prevent fiber staining. Phosphate content varies from a high of 57 percent in heavy-duty laundry powders to less than 10 percent in light-duty liquids. Phosphates are also present in almost all soaps.

The soap and detergent representatives acknowledged that phosphates affect the nutrient balance of waters, but believed the exact role in algal growth and eutrophication had not been clearly defined. They pointed out that in 1958, 70 percent of the elemental phosphorus sold went into fertilizers and 13 percent as built detergents.

Phosphorus from municipal discharges. Direct discharges of phosphorus to Lake Erie from municipal sewage treatment plants constitute about 80 percent of the total input from all sources. No measured values are available for urban runoff in the Lake Erie basin, but a study by Weibel, Anderson, and Woodward (1964) revealed that an urban acre yields 2.5 pounds of soluble phosphate (PO_4) per year. This would comprise a relatively small percentage of the total inputs.

Phosphorus from rural runoff. It has been demonstrated that municipal and industrial phosphorus inputs constitute about 85 percent of the total. The remaining 15 percent is attributable to rural runoff. This was verified by applying values established by Englebrecht and Morgan (1961) for an area in Illinois to the Lake Erie drainage basin.

Instruction V. "Determine the nutrient balance of Lake Erie."

Phosphate balance. The concentration of total PO_4-P leaving Lake Huron was shown on Page 8. This results in a discharge of total PO_4-P from Lake Huron of less than 20,000 lbs/day. That amount of total phosphate leaving the Detroit River to enter Lake Erie is approximately 86,000 lbs/day, resulting in a pickup between Lakes Huron and Erie of 66,000 lbs/day.

The discharge of phosphate by areas is summarized in Table 3.

TABLE 3

DISCHARGE OF PHOSPHATES TO LAKE BY AREAS

Area	Total Phosphate-P Lbs/day
Michigan-Ontario	
Discharge from Lake Huron	<20,000
Connecting channels area	66,000
Michigan tributaries to Lake Erie	2,000
Ohio	
Municipal & industrial (shoreline)	28,000
Ohio tributaries	20,000
Pennsylvania & New York	6,000
Ontario, other sources	10,000
Sum of major known sources	152,000
Discharged at Niagara River	50,000

Excluding the discharge from Lake Huron, of the 132,000 lbs/day of total phosphates expressed as P discharged to Lake Erie, approximately 112,000 lbs. come from municipal and industrial wastes, and 20,000 lbs. from rural land runoff. Of the municipal contribution, 70,000 lbs/day come from detergents, 30,000 from human excreta, 6,000 from urban land runoff, and 6,000 from industrial wastes. These totals are summarized in Table 4.

TABLE 4

TOTAL PO_4 INPUTS TO LAKE ERIE BY SOURCES

Source	PO_4-P Lbs/day
Lake Huron	<20,000
Rural land runoff	20,000
Municipal	
Detergents	70,000
Human excreta	30,000
Urban land runoff	6,000
Industrial (direct discharge)	6,000
TOTAL	152,000

Since only 50,000 lbs/day are discharged via the Niagara River, Lake Erie retains 102,000 lbs/day. Part of this amount is utilized by algae, small animals, and fish, part becomes locked in the sediments, and part is recycled and reused by the biomass.

Since the contribution of total PO_4-P from domestic wastes is about 3.5 lbs/cap/yr and 11 million persons live in the Lake Erie basin below Lake Huron, the annual contribution from municipal sources is 38,500,000 pounds.

Instruction VI. "Identify the various nutrients affecting Lake Erie water quality and determine which are susceptible to control."

Specialists who met with the committee mentioned nutrient substances such as nitrogen, potassium, vitamins, and carbon, but under present knowledge, phosphorus is the most important element and the one most susceptible to control. Nitrogen occurs in nature and can be fixed by certain bacteria. Potassium is sufficiently abundant in natural waters, and the role of vitamins and other growth substances is not well defined.

Instruction VII. "Identify other Lake Erie problems and explore ways of dealing with them."

Many other nutrient elements are recognized as requirements for algal production and growth, including many trace elements. Information is lacking as to the role of the trace elements and the possibilities for removal.

The committee recognized a need, in the phosphorus problem, of determining more exact figures on the contribution from various sources such as runoff from soil, animal wastes, and algae decomposition. It was brought to the attention of the committee that bottom sediment storage may contribute to the phosphorus supply of the lake water. However, available data indicate that the hypolimnetic buildup of phosphorus is reprecipitated at fall turnover of the lake water.

The committee has become aware of many of the problems which will be involved in removing a very high percentage of the phosphorus contribution to Lake Erie. It is recognized that percentage of phosphate removal must be increased with population growth and economic expansion and that ultimate disposal of nutrients will become increasingly more important in order to prevent their return to the lake.

Other problems of pollution are also recognized by the committee, such as increasing dissolved inorganic substances throughout the lake; bacterial, color, suspended solids, and floating solids problems along the shore; and special local problems caused by large industrial and municipal waste discharges, where, because of volume, treatment must be highly refined.

The following are present or potential problems in Lake Erie:

Toxic effect of algae
Botulism in waterfowl
Dumping of dredgings
Exploration for oil and gas
Taste and odor problems in drinking water
Short filter runs
Pollution by vessels
Uniformity of regulations on marine toilets
Uniformity of fish laws
Effects of lake levels on Cladophora

CONCLUSIONS

1. The major pollution problem in Lake Erie results directly or indirectly from excess algae. These growths are stimulated by nutrients resulting from man's activities.

2. Silts containing nutrients are being contributed to the lake from dredging operations, urban and agricultural runoff, and shore erosion.

3. Wind-induced currents transport nutrients and silt over wide areas of the lake.

4. Reliable long-term records for phosphorus and nitrogen are not available for Lake Erie waters.

5. The one nutrient most susceptible to control is phosphorus.

6. Phosphorus entering the lake originates from municipal wastes, rural land runoff, and industrial wastes. About 80 percent is attributable to municipal wastes.

7. About 66 percent of the phosphorus in municipal wastes is from detergents.

8. Earlier data on phosphorus are difficult to interpret due to lack of information on the analytical procedure used and the method of expressing the results.

9. Water quality problems will likely occur when the concentrations of soluble phosphorus and inorganic nitrogen exceed 0.01 mg/l and 0.30 mg/l respectively.

10. Water quality objectives should be established that will prevent nuisance algae conditions.

11. Even if water quality objectives are met, a reduction in frequency and intensity of algal nuisance conditions will be gradual.

12. Water quality objectives for Lake Erie should be established so that present high quality water will be preserved and the waters will be improved in the areas where nuisance conditions now exist.

13. Efforts to limit the growth of the filamentous alga Cladophora by the application of chemicals in the lake have been successful only on a small scale. Experience has demonstrated it is not feasible to apply these techniques to large areas. Chemical control of plankton algae is also impractical.

14. The quality of the Lake Erie fishery has declined. A significant factor in the decline of the more desirable species has been the destruction of suitable environment within which they could successfully complete their life cycle and be maintained in abundance.

RECOMMENDATIONS

1. The following level of phosphate and inorganic nitrogen expressed as P and N should be established as the water quality objective for Lake Erie.

Location (See Fig. 2)	Total PO_4-P mg/l	Sol PO_4-P mg/l	Inorganic N mg/l
Areas 1, 2, 3 & 4	0.025	0.010	0.3
Areas 5, 6 & 7	0.015	0.007	0.3

2. The following points should be established to measure P and N water quality at locations in Recommendation 1:

Location	Points of Measure
Areas 1, 2, 3 & 4 (See Fig. 2)	Range Pte. Mouillee to Detroit River Light (2,000, 8,000 and 13,000 feet offshore), average of these three stations Toledo Harbor lighthouse Raisin River channel buoy No. B1 South Bass Island and Pelee Passage lights Water intakes of: Toledo, Ohio Port Clinton, Ohio Sandusky, Ohio Vermilion, Ohio Lorain, Ohio Cleveland Electric Illuminating Co. at Eastlake, Ohio Industrial Rayon Corp. at Fairport, Ohio Intake East 2 miles of mouth of Ashtabula, Ohio Conneaut, Ohio
Areas 5, 6 & 7 (See Fig. 2)	Water intake cribs of: Cleveland, Ohio Buffalo, New York Erie, Pennsylvania Any point in central or eastern basin 2 miles from shore or beyond

3. These levels proposed for nutrient objectives should not be exceeded in more than 20 percent of the samples taken in any one year. To measure the nutrient water quality, samples should be taken at least once per month. Sample collection should be 3 feet below surface for mid-lake stations and inside the water plant from the raw water tap for the water intake stations.

Nutrient Control

4. Industry, the Federal Government, and the States should promote and encourage accelerated research and development of a suitable product solution to the phosphate problem.

5. Processes must be developed and employed to effect high phosphorus removal.

6. Phosphates removed by treatment must not be returned to a water course.

7. Broad public support should be given to the Department of Agriculture, State agricultural agency, and local conservancy district programs to control nutrient runoff from agricultural lands.

8. The USGS, The Corps of Engineers, and various State agencies should strengthen their programs to reduce further soil erosion in the Lake Erie basin.

9. The practice of dumping in Lake Erie pollutional materials dredged from rivers and harbors should be stopped.

Terminology, Analytical Methods, and Data Reporting

10. Concentrations of phosphates, both soluble and total, in surface waters should be expressed as elemental phosphorus (P).

11. Samples should be analyzed for total phosphorus and soluble phosphorus using the stannous chloride method, including persulfate and extraction. (This method is attached in Appendix B.) Where a particular laboratory departs from the method outlined in the appendix it should be clearly indicated and documented that in all concentrations encountered in surface water and with interferring substances usually encountered that the method yield results within the limits of reproducibility of the recommended method.

12. Sewage treatment plants should regularly test for total and soluble phosphorus under direction of the State water pollution control agency and results should be reported to the State agency.

Recommended Studies

13. Research should be encouraged that would explore procedures for recovering phosphorus.

14. The Bureau of Commercial Fisheries, the FWPCA, the States, and other agencies should increase the tempo of research programs in Lake Erie to more clearly define all the factors adversely affecting the fishery, municipal water supplies and recreational uses.

15. Research should also be directed toward the following problems:

Toxic effects of algae
Botulism in waterfowl
Exploration of oil and gas
Taste and odor problems in drinking water
Short filter runs at water plants
Pollution by vessels
Uniformity of regulations on marine toilets
Uniformity of fish laws
Effect of lake levels on Cladophora

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APPENDIX A

PHOSPHATE REPORTING

The more common methods for expressing the results of chemical determinations for phosphorus vary as to the form of phosphorus used. The most common methods express the results as P_2O_5 (Phosphorus pentoxide), PO_4 (phosphate) and P (phosphorus). The relationship between these methods of expression are:

$$1 \text{ mg/l } P = 2.29 \text{ mg/l } P_2O_5 = 3.06 \text{ mg/l } PO_4$$

$$1 \text{ mg/l } PO_4 = 0.75 \text{ mg/l } P_2O_5 = 0.33 \text{ mg/l } P$$

$$1 \text{ mg/l } P_2O_5 = 1.34 \text{ mg/l } PO_4 = 0.44 \text{ mg/l } P$$

The Committee decided that results or criteria should be reported for total phosphorus as P and soluble phosphorus as P to be consistent with Sawyer and most of today's investigators.

APPENDIX B

ANALYTICAL METHOD FOR THE MEASUREMENT OF TOTAL PHOSPHATE EXPRESSED AS TOTAL PHOSPHORUS

This method is according to 12 ed. Standard Methods, Method C, p. 236 with some modifications.

1. General Discussion

1.1. Principle: The total-phosphate content of the sample includes all the soluble orthophosphate and polyphosphates, and insoluble phosphates precipitated during storage. If any insoluble phosphates are present, for practical purposes they are assumed to be insoluble orthophosphate. It is understood that total phosphate is not to include insoluble phosphates that may have been present in the original water and removed in sampling, unless expressly requested; in that case, such insoluble phosphate will be reported separately. Condensed phosphates, such as pyro-, tripoly-, and higher-molecular-weight species (from commercial phosphates like hexametaphosphate), are not normally present in natural waters, but are frequently added in the course of water treatment. The concentration employed depends on the application. Polyphosphates do not respond appreciably to the orthophosphate tests but can be hydrolyzed to orthophosphate by boiling with acid. Also, the insoluble phosphates can be dissolved by boiling with acid. Then, with the proper combinations of filtration and boiling with acid and the orthophosphate value, both the polyphosphates and insoluble phosphates can be determined as their equivalent PO_4.

1.2. Interference: Interference from iron should not exceed 0.04 mg Fe in the portion taken for analysis. At least 25 mg/l soluble silicates can be tolerated. Color and turbidity also interfere. Chromate and strong oxidizing agents, such as peroxide, bleach the blue color. Interference from nitrite (which also bleaches the blue color) can be overcome by adding 0.1 g sulfamic acid to the sample before adding the molybdate. Because of the very low PO_4 range, contamination is a problem.

Extracting the heteropoly acid into an immiscible solvent before reduction greatly reduces the number of interferences; however, it does not remove interference from arsenic and germanium. Extraction also reduces the amount of polyphosphate determined with orthophosphate.

1.3. Minimum detectable concentration: The minimum detectable concentration is about 0.01 mg/l PO_4. The sensitivity at 50 percent transmittance is about 0.01 mg/l for 1 percent change in transmittance.

2. Apparatus

2.1. Colorimetric equipment: Visual comparison in nessler tubes is not normally recommended, because of the difficulty in meeting the time requirement to obtain accurate results. One of the following is required:

a. Spectrophotometer, for use at approximately 690 mμ. The color system also obeys Beer's law at 650 mμ, with somewhat reduced sensitivity, in the event the instrument available cannot be operated at the optimum wave length. A light path of 0.5 cm or longer yields satisfactory results.

b. Filter photometer, provided with a red filter exhibiting maximum transmittance in the wave length range of 600-750 mμ. A light path of 0.5 cm or longer yields satisfactory results.

2.2. Filtration equipment: Membrane Filter

2.3. Acid-washed glassware: This may be of great importance, particularly when determining low concentrations of phosphate. Phosphate contamination is common owing to the formation of thin films or absorption on iron oxide films on glassware. Commercial detergents containing phosphate should be avoided. Glassware should be cleaned with hot dilute HCl and rinsed well with distilled water.

3. Reagents

3.1. Phenolphthalein indicator solution: Either the aqueous (a) or alcoholic (b) solution may be used.

a. Dissolved 5 g phenolphthalein disodium salt in distilled water and dilute to 1 liter. If necessary, add 0.02N NaOH dropwise until a faint pink color appears.

b. Dissolve 5 g phenolphthalein in 500 ml 95 percent ethyl alcohol or isopropyl alcohol and add 500 ml distilled water. Then add 0.02N NaOH until a faint pink color appears.

3.2. 10N H_2SO_4

Potassium persulfate $K_2S_2O_8$

3.3. Sodium hydroxide 1.0N. Dissolve 40 g NaOH in a small quantity of distilled water and dilute to 1 liter.

3.4. Stock phosphate solution: Dissolve in distilled water 0.7165 g anhydrous potassium dihydrogen phosphate, KH_2PO_4, and dilute to 1,000 ml; 1.00 ml=0.500 mg PO_4.

3.5. Standard phosphate solution: Dilute 100.0 ml stock phosphate solution to 1,000 ml with distilled water; 1.00 ml=50,0 µg PO_4.

3.6. Ammonium molybdate reagent (1): Dissolve 25 g $(NH_4)_6Mo_7O_{24}.4H_2O$ in 175 ml distilled water. Cautiously add 280 ml conc H_2SO_4 to 400 ml distilled water. Cool, add the molybdate solution, and dilute to 1 liter.

3.7. Stannous chloride reagent (1): Dissolve 2.5 g of a fresh supply of $SnCl_2;2H_2O$ in 100 ml glycerol. Heat in a water bath and stir with a glass rod to hasten dissolution. This reagent is stable and requires neither preservatives nor special storage.

3.8. Reagents for extraction:

a. Benzens-isobutanol solvent: Mix equal volumes of benzene and isobutyl alcohol. (CAUTION: This solvent is highly flammable.)

b. Ammonium molybdate reagent (II): Dissolve 40.1 g $(NH_4)_6Mo_6O_{24}.4H_2O$ in approximately 500 distilled water. Slowly add 396 ml molybdate reagent (1). Cool, and dilute to 1 liter.

c. Alcoholic sulfuric acid solution: Cautiously add 20 ml conc H_2SO_4 to 980 ml methyl alcohol with continuous mixing.

d. Dilute stannous chloride reagent (II): Mix 8 ml stannous chloride reagent (I) with 50 ml glycerol. This reagent is stable for at least 6 months.

4. Procedure

4.1. If precipitate or turbidity is present in the bottled sample, two portions must be taken for analysis. One should consist of 50 ml of the filtered sample. (See Sec. 2.2 for procedure on filtering the sample.) The other portion should consist of 50 ml of thoroughly mixed unfiltered sample. To each of the 50 ml portions, or aliquots diluted to 50 ml, add 1 drop of phenolphthalein indicator solution. If a red color develops, add 10N H_2SO_4 dropwise to discharge color. Then add 1 ml of 10N H_2SO_4 in excess and .4 g pottasium persulfate to each.

4.2. Digest at boiling temperature for at least 30 minutes. Remove any suspended matter by filtration. Add 1 drop of phenol-phthalein indicator solution and neutralize to a faint pink color with sodium hydroxide solution. Restore portions to original 50 ml volume with distilled water.

4.3. Determine the orthophosphate content of each treated portion as described in 4.4, 4.5 and 4.6, adapted to a sample volume of 50 ml.

4.4. Add, with thorough mixing after each addition, 4.0 ml molybdate reagent (I)and 0.5 ml (10 drops) stannous chloride reagent (I). The rate of color development and the intensity of color depend on the temperature of the final solution, each 1°C increase producing about 1 percent increase in color. Hence, samples, standards, and reagents should be within 2°C of one another and at a temperature between 20° and 30°C.

4.5. After 10 min. but before 12 min., employing the same specific interval for all determinations, measure the color photometrically at 690 mμ and compare with a calibration curve, using a distilled-water blank. Light path lengths suitable for various phosphate ranges are as follows:

Approx PO_4 Range	Light Path
mg/l	cm
1-6	0.5
0.3-3	2
0.02-0.5	10

A blank must always be run on the reagents and distilled water. Inasmuch as the color at first develops progressively and later fades, it is essential that timing be the same for samples as for standards. At least one standard should be tested with each set of samples or once each day that tests are made. The calibration curve may deviate from a straight line at the upper concentrations of the 1-6 mg/l range.

4.6. Extraction: When increased sensitivity is desired or interferences need to be overcome, extract the phosphate as follows: Pipet a suitable aliquot of sample into a 100-ml graduated extraction cylinder and dilute, if necessary, to 40 ml with distilled water. Add 50.0 ml benzene-isobutanol solvent and 15.0 ml molybdate reagent (II). Close at once and shake vigorously for exactly 15 sec. Any delay increases the amount of polyphosphate, if present, which will be included in the orthophosphate value. Remove the stopper and withdraw 25.0 ml of separated organic layer, using a pipet and a safety aspirator. Transfer to a 50-ml volumetric flask, add 15 to 16 ml alcoholic sulfuric acid solution, swirl, add 10 drops (0.50 ml) dilute stannous chloride reagent (II), swirl, and dilute to the mark with alcoholic sulfuric acid. Mix thoroughly: after 10 min. but before 30 min., read against the blank at 625 mμ. Prepare the blank by carrying 40 ml distilled water through the same procedure as the sample. Read the PO_4 concentration from a calibration curve prepared by taking known phosphate standards through the same procedural steps as the samples.

5. Calculation

$$\text{mg/l } PO_4 = \frac{\text{mg } PO_4 \times 1{,}000}{\text{ml sample}}$$

Express all results as mg/l P by multiplying the value obtained for PO_4 by the factor 0.326. The end result is therefore expressed as total phosphorus.

6. Precision and Accuracy

The precision approximates ± 0.001 mg (0.02 mg/l) or about ± 2 percent of the result, whichever is the larger numerical value. The accuracy depends on the amount of interferences and the apparatus used. Serious differences between laboratories reporting on the same sample can result from dirty glassware and inattention to phosphate-bearing suspended matter.